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MONTANA STATE HIGHWAY DEPARTMENT

HIGHWAY PLANNING SURVEY

IN COOPERATION WITH

PUBLIC ROADS ADMINISTRATION

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ENGINEERING ECONOMIC ANALYSIS
OF FEDERAL AID SECONDARY ROUTE 324
BETWEEN ARMSTEAD AND BRENNER
AND PROPOSED EXTENSION TO MONTANA-IDAHO BOUNDARY
IN BEAVERHEAD COUNTY

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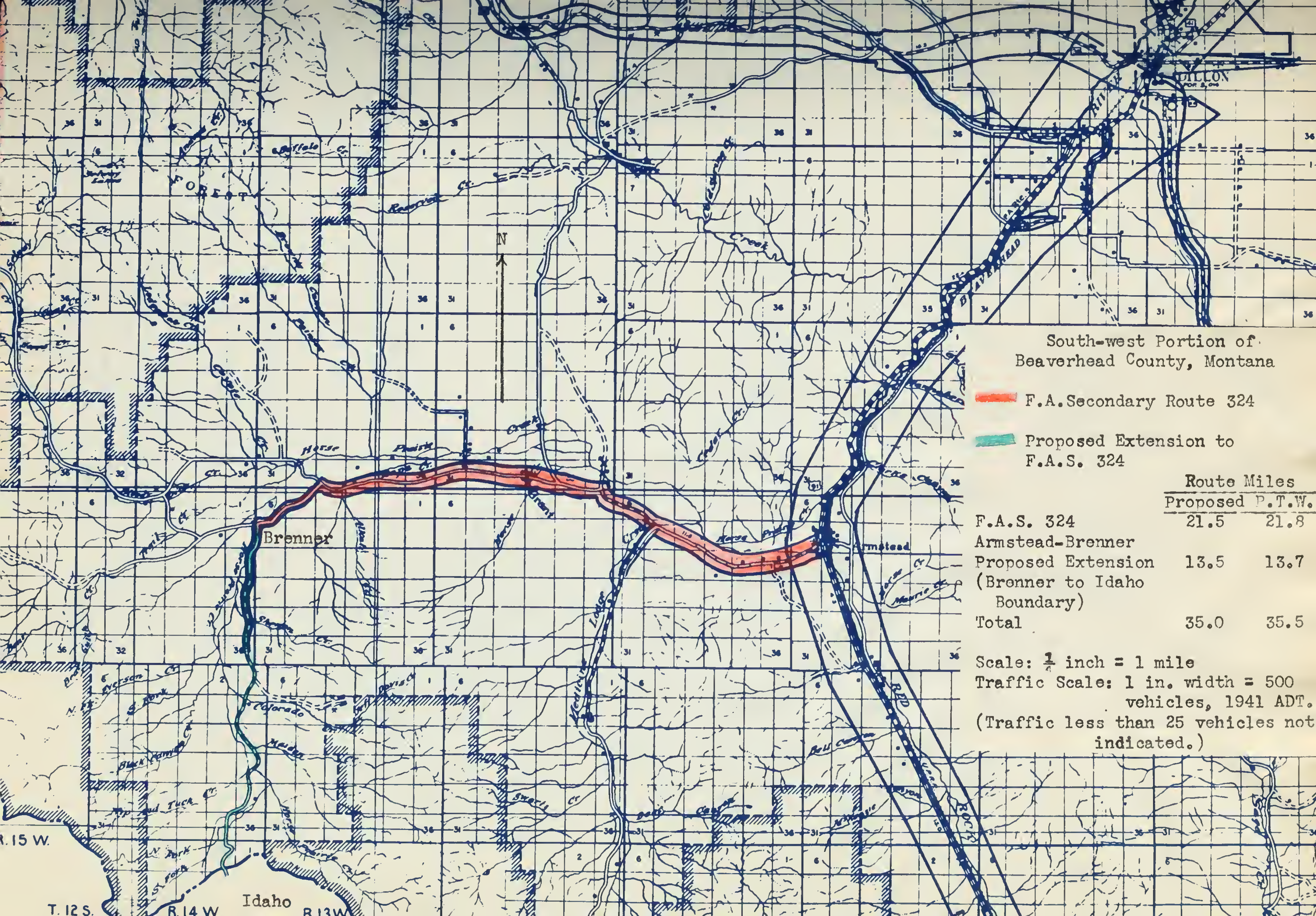
ENGINEERING ECONOMIC ANALYSIS OF FEDERAL AID SECONDARY ROUTE 324 BETWEEN ARMSTEAD AND BRENNER AND PROPOSED EXTENSION TO MONTANA-IDAHO BOUNDARY IN BEAVERHEAD COUNTY

November 1946



South-west Portion of
Beaverhead County, Montana

🟥 F.A.Secondary Route 324

🟩 Proposed Extension to
F.A.S. 324

	Route Miles	
	Proposed	P.T.W.
F.A.S. 324 Armstead-Brenner	21.5	21.8
Proposed Extension (Brenner to Idaho Boundary)	13.5	13.7
Total	35.0	35.5

Scale: $\frac{1}{4}$ inch = 1 mile
Traffic Scale: 1 in. width = 500
vehicles, 1941 ADT.
(Traffic less than 25 vehicles not
indicated.)

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MONTANA HIGHWAY PLANNING SURVEY

GUIDES FOR ESTIMATING 1960 TRAFFIC

1.	100% =	1941 traffic	Applies to:
2.	110% = to 125%	Traffic if route is unimproved at present time but expected to be improved by 1960.	F.A., F.A.S. and Class 1, 2, & 3 Forest Highways. Applies to sparcely settled rural areas. (Add extra traffic generated by logging activities on timber utilization roads or other major industries and traffic induced by these activities).
3.	125% = to 150%	Traffic if route is unimproved at present time but expected to be improved by 1960.	F.A., F.A.S. and Class 1, 2, & 3 Forest Highways. Applies in checkerboard well-settled rural areas or on through-roads. (Add extra traffic generated by logging activities on timber utilization roads or other major industries and traffic induced by these activities).
4.	150% = to 200%	Traffic if route is unimproved at present time but expected to be improved by 1960.	F.A., F.A.S. and Class 1,2, & 3 Forest Highways. This applies in exceptional cases such as bottlenecks and natural cutoffs. Some cases, of course, might be much more but these special conditions would require special analysis. (Add extra traffic generated by logging activities on timber utilization roads or other major industries and traffic induced by these activities).

Note: Date of expected improvement does not change traffic estimates for 1960.

130% = expected secular growth 1941 to 1960 -- to be applied to all above conditions except traffic generated by logging activities, or other major industries.

Applies to all roads now constructed.
(Without any of above increases)

Average summer maximum traffic equals double average ADT except on predominately recreational routes where factor might be as high as 3.
Average summer maximum traffic equals average of several maximum summer days.
Maximum hour equals 10% of maximum summer ADT. (Usual public traffic), or 15 to 20% on roads used by both the public and by major logging operations or other major industries.

Montana State Highway Department
Traffic and Planning Section
Public Roads Administration
Basic Design Categories
Table No. 1

Standard	Average Daily Traffic	Classification	Max. Grade	Max. Curvature (Degree)	Sight Distance				Shoulder Width	Width of Road Bed at Grade	Width of Surfacing	Minimum Type of Surfacing	Minimum Base Course
					Non Passing			Passing					
					Horiz. Curvature (Degree)	Vertical Curvature (Algebraic Difference)	Feet	Feet					
0	0-200	20 M 40	7	14	14	SEE TABLE NO. 2.	280	800	3	24	18	Under 1" Oil	5"
1	201-400	50 M 40	7	14	14		290	800	4	28	20	2" Oil	6"
2	401-800	100 M 40	7	14	14		310	1100	5	32	22	2½" Oil	8"
3	801-1800	200 M 40	7	14	14		320	1100	6	34	22	2½" Oil	8"
4	1801-3500	300 M 40	7	14	14		330	1100	8	38	22	2½" Oil	8"
5	0-200	20 M 60	6	6	6		460	1700	3	26	20	Under 1" Oil	5"
6	201-400	50 M 60	6	6	6		460	1700	4	30	22	2" Oil	6"
7	401-800	100 M 60	6	6	6		470	2100	5	32	22	2½" Oil	8"
8	801-1800	200 M 60	6	6	6		480	2100	6	34	22	2½" Oil	8"
9	1801-3500	300 M 60	6	6	6		500	2100	8	38	22	2½" Oil	8"

Note: Roads having over 3500 vehicles per day require special design.

TABLE NO. 2

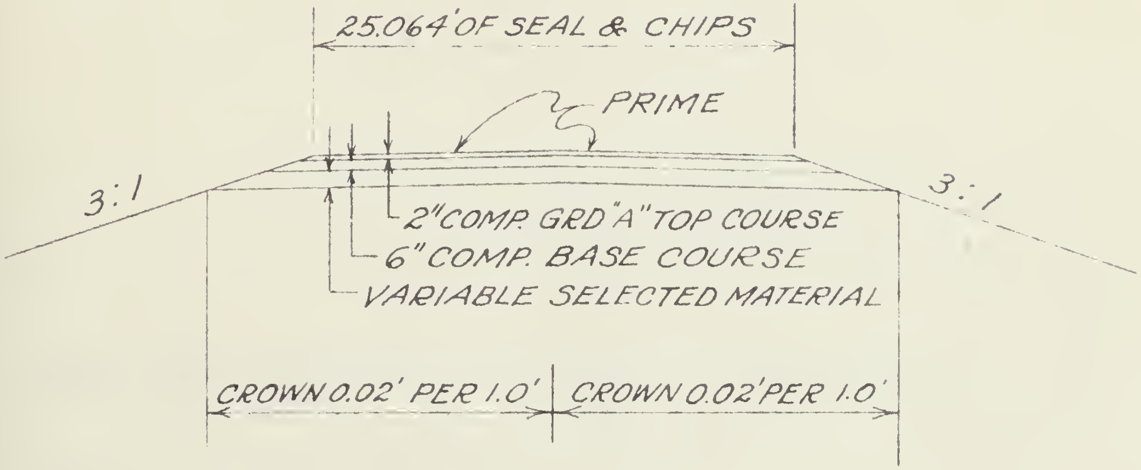
Table giving length of vertical curve required for various
Non - passing sight distances

December 18, 1943

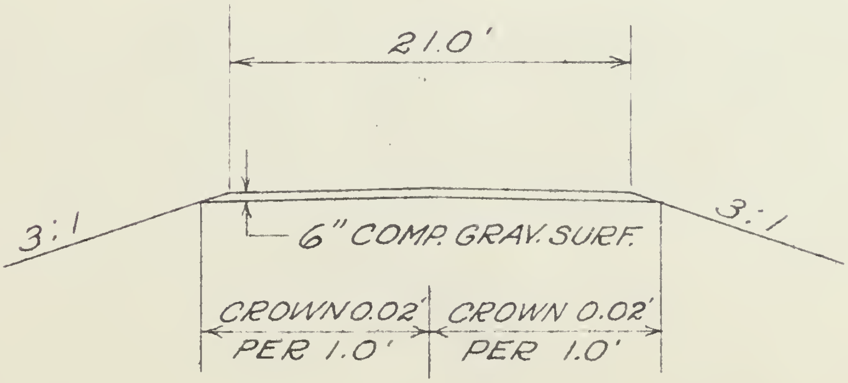
Algebraic Difference between grades for convex curvature.	Length of vertical curve for a Non-passing sight distance of: 280 feet	Length of vertical curve for a Non-passing sight distance of: 290 feet	Length of vertical curve for a Non-passing sight distance of: 310 feet	Length of vertical curve for a Non-passing sight distance of: 320 feet	Length of vertical curve for a Non-passing sight distance of: 330 feet	Length of vertical curve for a Non-passing sight distance of: 460 feet	Length of vertical curve for a Non-passing sight distance of: 470 feet	Length of vertical curve for a Non-passing sight distance of: 480 feet	Length of vertical curve for a Non-passing sight distance of: 500 feet
1.00	96	103	117	125	133	258	269	281	305
2.00	191	205	234	250	266	516	539	562	610
3.00	287	308	352	375	398	774	808	843	915
4.00	382	410	469	500	531	1032	1078	1124	1220
5.00	478	513	586	624	664	1290	1347	1405	1524
6.00	574	615	703	749	797	1548	1616	1686	1829
7.00	669	718	820	874	930	1806	1886	1967	2134
8.00	765	820	938	999	1062	2064	2155	2248	2439
9.00	860	923	1055	1124	1195	2322	2425	2529	2744
10.00	956	1026	1172	1249	1328	2581	2694	2810	3049
11.00	1052	1128	1289	1374	1461	2839	2963	3091	3354
12.00	1147	1231	1406	1499	1594	3097	3233	3372	3659
13.00	1243	1333	1524	1623	1726	3355	3502	3653	3963
14.00	1339	1436	1641	1748	1859	3613	3771	3934	4268

SECONDARY SYSTEM

100 VEHICLES AND LESS THAN 400
AV. 24-HOUR TRAFFIC



UNDER 100 VEHICLES
AV. 24-HOUR TRAFFIC



MONTANA HWY. COMM.
JUNE 1, 1945

REVISED MAR. 25, 1946

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Engineering Economic Analysis
# of Federal Aid Secondary Route 324
Between Armstead and Brenner
and Proposed Extension to Montana-Idaho Boundary
in Beaverhead County

I. SUMMARY

The presently designated F.A. Secondary Route 324 should be completely constructed from Armstead to Brenner according to the results of analysis developed in this report.

It is further recommended that F.A.S. 324 be lengthened by the herein Proposed Extension of 13.7 miles of secondary road to Bannock Pass on the Montana-Idaho Boundary and improved when funds are available.

The Beaverhead County Commissioners have expressed themselves as favoring the construction of this entire route to Bannock Pass in lieu of other roads in the county with somewhat heavier traffic. Since these other (mostly shorter) routes are in good condition under County maintenance, the County Commissioners and the State Highway Department have given preference to the Armstead-Idaho boundary road because it offers greater possibilities of serving more people, when improved, than any of the other roads.

The roads on the Idaho side leading into Leadore and to the Salmon River Highway have been improved and are being maintained in good condition. When the Montana section is completed, the people of Leadore and considerable surrounding area can reach the railhead at Armstead by traveling a distance of from 45 to 86 miles. From Leadore south to the railhead at Dubois, Idaho, is 96 miles, and from Leadore north to the railhead at Darby, Montana, is 127 miles. Thus residents entering the road up to a distance of 41 miles north of Leadore, and 26 miles south of Leadore, would find their shortest route to a railhead via Leadore and on into Armstead. This total distance of 67 miles includes the communities of Baker, Tendoy, Lemhi, and Gilmore, besides Leadore with a population of about 300. Therefore, it may be estimated that between four and five hundred residents of this area would find it to their advantage to save up to 51 miles in travel to a railhead by going to Armstead once the Montana section of the route was improved.

SUMMARY TABLE

	Miles	1941 A.D.T.**	1960 A.D.T.	Annual Total Cost	Income	Benefits	*Composite Solvency Quotient
Route F.A.S. 324	21.5	58	151	$24,000	$ 9,946	$24,406	1.012
Proposed Extension	13.5	24	62	$11,348***	$ 2,346	$ 3,665	0.375
Combined Routing	35.0	45	117	$35,348	$12,292	$28,071	0.807

*For a complete table of Solvency Results, see page 14 of this report.
**A.D.T. = Average Daily Traffic (number of vehicles)
***Construction cost of six miles of Forest Service Road not included.

Significance of Solvency Quotients:

These analyses have been set up according to principles of the Oregon Highway Department's Solvency Quotient method. Route F.A.S. 324 will return slightly more than its annual cost to the state in gasoline tax revenue and in values of benefits to road users, as indicated by the composite solvency quotient of 1.012.

Analysis of the total routing of 35 miles, which includes the Proposed Extension, gives a composite quotient of 0.807 which means that nearly 81% of its annual construction cost would be returned in gasoline tax revenue and in benefits to the road users.

II. SUMMARY (cont'd)

By the same interpretation, the Proposed Extension of 13.5 miles, shows that it would return 35.7% of its cost. However, this Quotient is based on a cost that does not include an estimated annual construction cost of $6,306 for 5.9 miles of Forest Service road which would be financed entirely from Federal funds.

These results should be interpreted from the standpoint of the entire state highway system. In Montana only a few of the main traveled roads would warrant construction, were Solvency Quotients the sole criterion. Income producing roads should have their surplus used in the construction of less roads which benefit the whole system. This can be done only so long as the system as a whole remains above the solvency level.

Better medical, fire protection, police, school, and mail facilities are benefits to the general public which must be given consideration but are not a part of this analysis.

II. ROUTE DESCRIPTIONS

F.A.S. 324: From a point on F.A. Route 3 in Armstead west via Grant to a county road junction in Sec. 7, T. 10 S. R. 13 W. This junction is known as Brenner.

Proposed Extension: From a county road junction in Sec. 7, T. 10 S. R. 13 W (Brenner) southerly to the Idaho State line at Bannock Pass to connect with a forest highway route in Idaho.

Economic and Engineering Conditions: The only towns on this routing are Armstead with an estimated population of about 100 and Grant with an estimated population of 20. The entire district has a population of 428 based on 1940 census data.

The topography of the region is generally rolling terrain and foot hills. Elevations are as follows: Armstead 5503 feet, Grant 5847 feet, Brenner 6252 feet, and Bannock Pass 7672 feet. The climate is severe with summer temperatures reaching 100°F. and winter temperatures dropping as low as -50°F. Blizzards and drifting snow are common winter occurances.

Grazing of cattle and sheep is the predominate industry. This stock raising is conducted by comparatively few ranches of large area. The population is thin and scattered. Any population increase, except anticipated normal secular growth, is highly improbable.

Armstead is served by the Union Pacific Railroad running north and south. There are now no other railroad facilities in the district. A few years ago the Gilmore and Pittsburgh rail line, that paralled our highway routing from Armstead to Bannock Pass, was abandoned. Large portions of this abandoned grade might be utilized in relocating the improved highway herein analyzed.

III. TRAFFIC

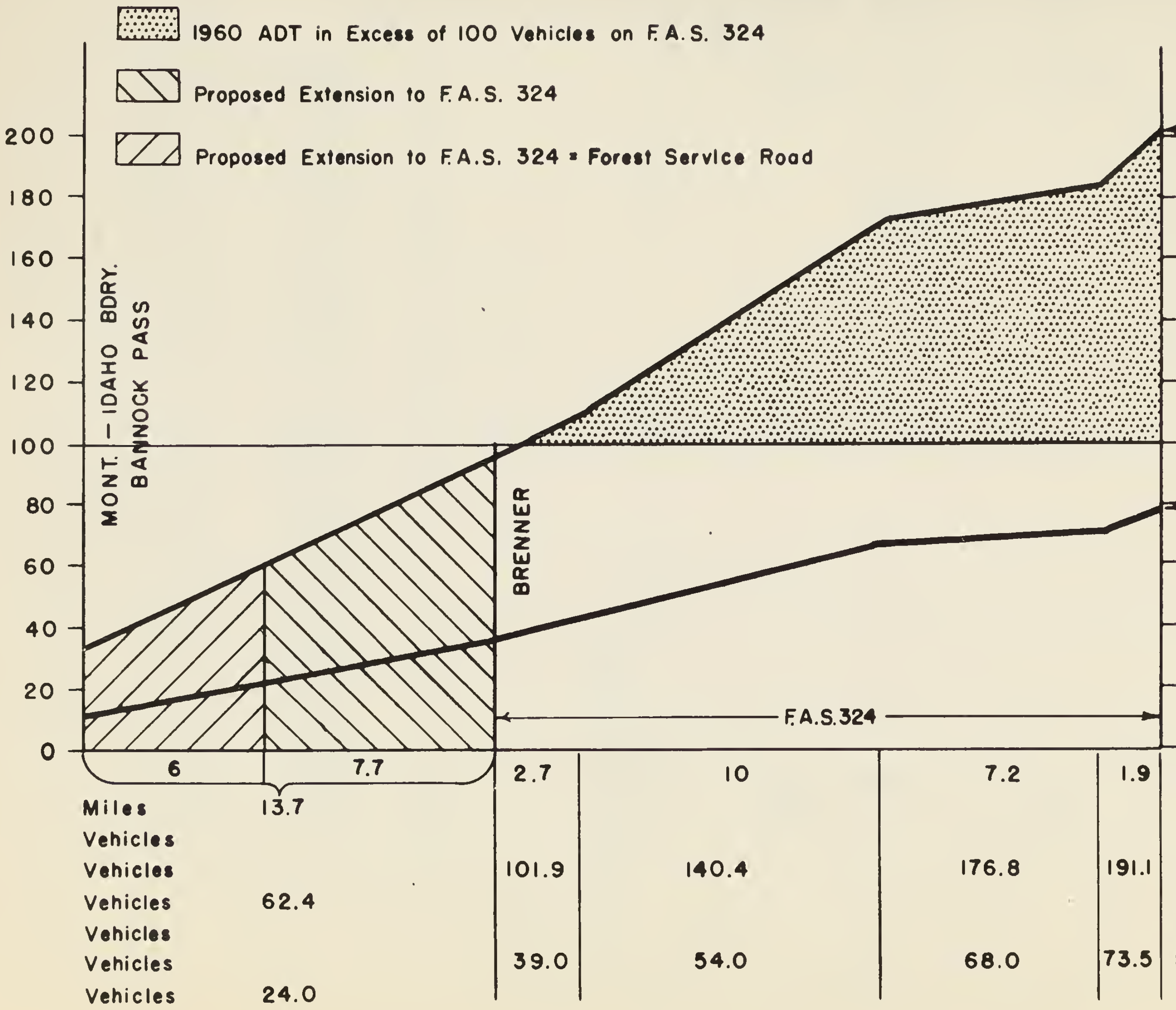
Our best assumption in predicting the economics of this area in 1960 is based on traffic trends which show close corelation with economic trends. There is nothing observable in the economic picture of the region to indicate more than average growth from the present to 1960.

However, besides acting as a feeder road to and from Armstead and serving neighborhood traffic, this road has latent possibilities for serving a section of Idaho with a population ranging between four and five hundred residents (as discussed in the third paragraph of the Summary on page 1), whose nearest rail facilities are at Armstead. The present earth road surface reveals its gumbo characteristics when wet. In our opinion as soon as this road is improved, there is every likelihood of a doubling of present traffic, a portion of which would be interstate commercial and tourist travel. Fast trucking of stock to a market or railway shipping point is becoming an increasingly important factor in livestock production. With these in mind, we have doubled the 1941 traffic for our estimate of traffic on completion of construction. We have also included a higher maintenance rate on the Proposed Extension mileage in anticipation of large snow removal costs.

The Traffic Volume Profile (see page 4) as expanded to 1960, shows that practically all of the Armstead to Brenner section will have an A.D.T. of between 100 and 200 vehicles. Therefore, an oiled surfaced road designed as illustrated on the upper portion of Typical Sections, page iv, prefatory assembly, is standard for this section.

The Proposed Extension with a 1960 A.D.T. of 62 vehicles would be constructed to a gravel surface as illustrated on the lower portion of the page of Typical Sections.

TRAFFIC VOLUME PROFILES FOR F. A. SECONDARY 324
AND PROPOSED EXTENSION
BEAVERHEAD COUNTY , MONTANA , NOV. 1946



1960 Traffic Volume as Expanded from 1941 Traffic

Vehicle	Miles
1941	1960
223.3	854.9
105.3	275.1
540.0	1404.0
489.6	1273.0
139.7	363.1
35.5 / 1497.9	35.5 / 4170.1
= 45.2	= 117.4

1941 Traffic Volume

35.5 = Total Miles

117.4 = 1960 ADT for Composite Total
151.0 = 1960 ADT for F.A.S. 324
62.4 = 1960 ADT for Proposed Extensions
45.2 1941 ADT for Composite Total
58.5 = 1941 ADT for F.A.S. 324
24.0 = 1941 ADT for Proposed Extensions

IV ECONOMIC ANALYSIS

A. AVERAGE DAILY TRAFFIC
Route F.A.S. 324 and Proposed Extension,
Beaverhead County, Montana, November, 1946

	1941 A.D.T.	Plus 100% on compl. of const.	Plus 30% 1960 A.D.T.
Route F.A.S. 324			
Passenger cars, Montana	38	76	99
Passenger cars, Foreign	5	10	12
Trucks, Light	14	28	37
Trucks, Medium	0.5	1	1.5
Trucks, Heavy	0.5	1	1.5
Total Traffic	58	116	151
Proposed Extension to F.A.S. 324			
Passenger cars, Montana	13	26	34
Passenger cars, Foreign	5	10	12
Trucks, Light	6	12	15
Trucks, Medium	*	*	0.5
Trucks, Heavy	*	*	0.5
Total Traffic	24	48	62
Composite Total Traffic	45	90	117

* Less than 0.5 vehicle

Notes and Comments

1941 A.D.T. derived from 1941 Traffic Profiles for Route F.A.S. 324 and proposed addition, see page 4.

The 100% increase on completion of construction is based on "Guides for estimating 1960 Traffic" (see p.iii Prefatory Assembly). This road is considered a bottle-neck because when wet the gumbo nature of the earth makes this road very difficult to travel.

The 30% increase to 1960 expands the traffic according to the normal growth rate based on normal increase in population and vehicle ownership.

ANNUAL COST CALCULATIONS
F.A.S. 324 and Proposed Extension, Beaverhead Co., Montana, Nov. 1946

	Average Cost Per Mile				
	Forest Service		Sub total	F.A.S. 324	Combined total
. Grading & Clearing etc.	$ 4,700	$ 4,700	$ 4,700	$ 4,700	$ 4,700
:. Gravel Base & Surface	4,400	4,400	4,400	4,400	4,400
:. Oil Surfacing	-	-	-	2,000	1,229
:. Major Drainage Structures	3,864	3,750	3,800	1,060	2,117
. Minor Drainage Structures	1,000	1,000	1,000	1,000	1,000
. Rights of Way	200	200	200	200	200
. Engineering & Administration Costs					
a. Grade & Gravel	800	800	800	-	309
b. Grade & Gravel & Oil	-	-	-	1,000	614
c. 5% of cost of major drainage	193	188	190	53	106
Subtotal	15,157	15,038	15,090	14,413	14,675
'lus 10% for Contingencies	1,516	1,504	1,509	1,441	1,468
'OTAL AVERAGE COST PER MILE	$16,673	$16,542	$16,599	$15,854	$16,143
Total cost for Project Miles	5.9 mi.	7.6.mi.	13.5 mi.	21.5 mi.	35.0 mi.
. Grading & Clearing, etc.	$27,730	$35,720	$63,450	$101,050	$164,500
'. Gravel Base & Surface	25,960	33,440	59,400	94,600	154,000
. Oil Surfacing	-	-	-	43,000	43,000
. Major Drainage Structures	22,800	28,500	51,300	22,800	74,100
. Minor Drainage Structures	5,900	7,600	13,500	21,500	35,000
. Rights of Way	1,180	1,520	2,700	4,300	7,000
. Engineering & Administration Costs					
a. Grade & Gravel	4,720	6,080	10,800	-	10,800
b. Grade & Gravel & Oil	-	-	-	21,500	21,500
c. 5% of cost of major drainage	1,140	1,425	2,565	1,140	3,705
Subtotal	89,430	114,285	203,715	309,890	513,605
lus 10% for Contingencies	8,943	11,429	20,372	30,989	51,361
OTAL UNAMORITIZED COST OF CONSTRUCTION	98,373	125,714	224,087	340,879	564,966
OTAL ANNUAL CAPITAL COST 20 years @2½%)	6,306	8,058	14,364	21,850	36,214
aintenance Costs	1,770	1,520	3,290	2,150	5,440
)TAL ANNUAL COSTS	$ 8,076	$ 9,578	$17,654	$ 24,000	$ 41,654

Cost of timber trestles has been based on recent cost of $100 per lineal foot.

' These Engineering and Administrations costs based on similar project costs experi-
 iced in the past.

:* All construction costs estimates herein have been assigned an interest rate of 2½%
) be amortized in 20 years. This time period is deemed significant of the service life
' the proposed improvement. It is believed that traffic will require roads of higher
andards as time goes on and thus require a greater outlay on reconstruction. Therefore,
ie road "as built" should lay up a reserve to meet probable increased construction costs
. the future.

** From consideration of various statistics ascertained in the course of the Highway
anning Survey, we have assigned a maintenance cost of $100 per mile per year for F.A.S.
4. Costs of $200 and $300 per mile have been estimated, for remaining sections in an-
:cipation of higher snow removal costs.

Route F.A.S. 324 and Proposed Extension, Beaverhead County, November 1946

Traffic Type	A.D.T. Vehicles	Average Annual Vehicles	Avg. Gross tons per Vehicle	Average Annual Gross Tons	Miles	Average Annual Ton-Miles	Unit net Revenues per Ton-Mile	Total Annual Net Revenues
Route F.A.S. 324								
Passenger cars, Montana	99	36,135	1.5	54,203	21.5	1,165,364	0.002188	$ 2,550
Passenger cars, Foreign	12	4,380	1.5	6,570	21.5	141,255	0.001799	254
Total Passenger Cars	111	40,515	1.5	60,773	21.5	1,306,620	-	2,804
Trucks, Light	27	13,505	3.27	44,161	21.5	949,462	0.003248	3,084
Trucks, Medium	1.5	548	6.88	3,770	21.5	81,055	0.002382	1,931
Trucks, Heavy	1.5	548	11.15	6,110	21.5	131,365	0.001619	2,127
Total Trucks	40	14,601	3.70	54,041	21.5	1,161,882	-	7,142
Total, all vehicles	151	55,116	2.08	114,814	21.5	2,468,502	-	$ 9,946
Proposed Extension								
Passenger cars, Montana	34	12,410	1.5	18,615	13.5	251,303	0.002188	$ 550
Passenger cars, Foreign	12	4,380	1.5	6,570	13.5	88,695	0.001799	160
Total Passenger Cars	46	16,790	1.5	25,185	13.5	339,998	-	710
Trucks, Light	15	5,475	3.27	17,903	13.5	241,691	0.003248	785
Trucks, Medium	0.5	183	6.88	1,259	13.5	16,997	0.002382	405
Trucks, Heavy	0.5	183	11.15	2,040	13.5	27,540	0.001619	446
Total Trucks	16	5,841	3.63	21,202	13.5	286,228	-	1,636
Total, all vehicles	62	22,631	2.05	46,387	13.5	626,226	-	$ 2,346

Col.

1. Average Daily Traffic for 1960 as developed in Table on page 5.
2. A.D.T. of Col. 1 multiplied by 365, the number of days in the year.
3. Avg. Gross ton figures for each class of vehicle were ascertained during course of research work by Planning Survey.
4. Avg. Annual Vehciles of Col. 2 multiplied by Avg. Gross Tons per Vehicle of Col. 3.
5. Length in miles of the proposed routes.
6. Avg. Annual Gross Tons of Col. 4 multiplied by Miles of Col. 5.
7. Income accrues by virtue of the Gasoline License Tax Levy. Unit net Revenues rates were derived from a general study conducted by the Planning Survey.

D. MILEAGE ELEMENT SAVINGS

Route F.A.S. 324 and Proposed Extension, Beaverhead County, Montana, Nov. 1946

	F.A.S. 324		Proposed Extension	
	New	Existing	New	Existing
*1. Distance				
Length (miles)	21.5	21.8	13.5	13.7
Distance saving (miles)	0.3		0.2	
Average Annual traffic (tons)	114,814		46,387	
Annual traffic saving (ton-mi.)	34,444		9,277	
Cost ($/ton-mile)	0.0198		0.0199	
Total annual saving	$682		$185	
*2. Surface				
Roadway surface type	oiled	earth	gravel	earth
Roadway surface type coefficient	0.03	0.28	0.19	0.28
Saving coefficient	0.25		0.09	
Avg. annual traffic (ton-mi.)	2,468,501		626,226	
Saving ($/ton-mile)	0.004945		0.001795	
Total annual saving	$12,207		$ 1,124	
*3. Rise and Fall				
Rise and Fall (feet)	936	1123	1775	2130
Saving (feet)	187		355	
Saving (foot-tons)	21,470,218		16,467,389	
Saving ($/foot-ton)	3.264×10^{-6}		3.973×10^{-6}	
Total annual saving	$70		$65	
*4. Gradient				
Gradients in per cent			2.45	2.94
Red'n. in gradient			0.49	
Avg. An. traffic (ton-mi.)			626,226	
Saving ($/ton-mile)			0.595×10^{-4}	
Total annual saving			$37	
*5. Alinement				
Curvature rating	8	0	6	0
Points improvement	8		6	
Saving (point-ton-miles)	19,748,008		3,757,356	
Saving ($/point-ton-mile)	0.0001		0.0001	
Total annual saving	$1,975		$376	
TOTAL ANNUAL MILEAGE ELEMENT SAVINGS	$14,934		$1,787	

Mileage Element Savings accrue to traffic as a result of decreased travel distance, rise and fall, and gradient, and also as a result of improved riding surface and alinement. Change in gradient was negligible on F.A.S. 324. All Mileage Element Factors tend to decrease wear and tear on engines and tires and increase the miles per gallon of fuel consumed.

*1, *2, *3, *4, and *5, see Details of Development on pages 9 and 10.

D. MILEAGE ELEMENT SAVINGS
Details of Development

1. **Distance:** Derivation of cost in dollars per ton-mile.

From col. 3 on page 7 of this report, we get 3.70 as average gross tons weight for all truck traffic on F.A.S. 324. Using this weight, we derive from Fig. 113 p. 274, Oregon Technical Bulletin 7, that 1.725 cents is the operating cost per ton-mile for this weight.

An A.D.T. of 40 trucks (col. 1, p. 7, this report) is 26.5% of a total A.D.T. of 151 vehicles. Using an operating cost of 2.07 cents per ton-mile for passenger cars we combine costs in the following expression to arrive at a composite operating cost of 1.978 cents per ton-mile:

Truck traffic = 0.265 x 1.725 = 0.457
Passenger car traffic = 0.735 x 2.070 = 1.521
Composite traffic = 1.978

In the same manner, using a gross weight of 3.63 tons for truck traffic consisting of 25.8% of the total traffic we arrive at a composite cost of 1.995 cents per ton-mile for traffic on the Proposed Extension.

2. **Surface:** a. Source of roadway surface type coefficient.

From page 278 and 288 of Oregon Bulletin 7, we copy the following table of coefficients Oregon has developed as a basis for evaluating roadways in relation to type of surface:

Unimproved earth	0.28
Loose gravel and crushed rock	0.19
Oiled surface (light treatment)	0.03
Bituminous and Portland cement concrete pavement	0.00

b. Savings in dollars per ton-mile.

The cost in dollars per ton-mile as determined above for distance savings when multiplied by the saving coefficient results in surface savings in dollars per ton-mile as illustrated below:

For F.A.S. 324 0.25 x 0.01978 = 0.004945
For Proposed Extension 0.09 x 0.01995 = 0.001795

3. **Rise and Fall:** a. Source of Rise and Fall feet.

From suitable elevations as controls and estimates made from profile maps, we arrive at an estimated number of feet of rise and fall for the sections of the routing.

b. Derivation of savings in dollars per foot-tons.

Using figure 123, p. 297 of Oregon Technical Bulletin 7, we find that a gross weight of 3.70 tons for trucks (see col. 2, p. 6 this report) gives $\$2.00 \times 10^{-6}$ s fuel cost per foot ton.

Using a cost of $\$3.72 \times 10^{-6}$ for passenger car costs, we combine costs in the ame manner as in 1. Distance, above, to arrive at a composite cost of $\$3.264 \times 10^{-6}$ er foot-ton:

Truck traffic $0.265 \times 2.00 \times 10^{-6} = 0.530 \times 10^{-6}$
Passenger car traffic $0.735 \times 3.72 \times 10^{-6} = 2.734 \times 10^{-6}$
Composite traffic $= 3.264 \times 10^{-6}$ dollars per foot-ton

In the same manner, using a gross weight of 3.63 tons for truck traffic consis-ing of 25.8% of the total traffic we arrive at a composite cost of $\$3.973 \times 10^{-6}$ per oot-ton for traffic on the Proposed Extension.

D. MILEAGE ELEMENT SAVINGS (Cont'd)

Gradient: Derivation of savings in dollars per ton-mile.

Using Table XLV on p. 301 of Oregon Technical Bulletin 7, with a gross weight
3.63 tons we interpolate values as follows:

$$\begin{array}{l}\text{Gradient of } 2.94 = 2.98 \times 10^{-4} \\ \underline{\text{Gradient of } 2.45 = 2.49 \times 10^{-4}} \\ \text{Difference of Gradient of } 0.49 = 0.49 \times 10^{-4} \text{ dollars per ton-mile}\end{array}$$

For passenger cars the cost is calculated as $0.49 \times 1.29 \times 10^{-4} = 0.632$ dollars
r ton-mile.

With a truck traffic percentage of 25.8, we combine in the following expression
arrive at a composite cost of 0.595×10^{-4} dollars per ton-mile for all traffic
the Proposed Extension.

$$\begin{array}{lll}\text{Truck traffic} & = 0.258 \times 0.490 \times 10^{-4} & = 0.126 \times 10^{-4} \\ \text{Passenger car traffic} & = 0.742 \times 0.632 \times 10^{-4} & = 0.469 \times 10^{-4} \\ \hline \text{Composite traffic} & & = 0.595 \times 10^{-4} \text{ dollars per ton-mile}\end{array}$$

Alinement: Source of curvature rating.

Curvature rating is based on a ten point scale considering 0 as a very poor
rvature rating and ten as a very high standard of curvature. This system is
apted from Oregon Bulletin 7, p. 302-305.

Savings in dollars per point-ton-mile has been derived by Oregon (see Bulle-
n p. 304) as \$0.0001 perpoint-ton-mile.

In addition to the improvement in alinement of route F.A.S. 324 and Proposed
tension, the proposed standard will improve the sight distances and supereleva-
ons. Thus, we consider an eight point improvement for F.A.S. 324 and a six point
provement for the Proposed Extension to be a reasonable estimate.

E. TIME ELEMENT SAVINGS

Route F.A.S. 324 & Proposed Extension, Beaverhead County, Montana, November 1946

	Route F.A.S. 324		Proposed Extension	
	New	Existing	New	Existing
Private Passenger Cars				
Average speed (Miles per hour) (1)	43	30	38	30
Distance (Miles)	21.5	21.8	13.5	13.7
Time (hours per trip)	0.5000	0.7267	0.3553	0.4567
Time savings per vehicle	0.2267		0.1014	
Value of Savings ($/vehicle-hour) (2)	$ 0.60		$ 0.60	
Annual traffic volume (3)	40,515		16,790	
Total value of time savings	$ 5,511		$ 1,022	
Trucks, Light				
Average speed (miles per hour) (1)	39	26	31	23
Distance (miles)	21.5	21.8	13.5	13.7
Time (hours per trip)	0.5513	0.8385	0.4355	0.5957
Time savings per vehicle	0.2872		0.1602	
Value of savings ($/vehicle-hour) (2)	$ 0.86		$ 0.86	
Annual traffic volume (3)	13,505		5,475	
Total value of time savings	$ 3,336		$ 754	
Trucks, Medium				
Average speed (miles per hour) (1)	35	22	28	20
Distance (miles)	21.5	21.8	13.5	13.7
Time (hours per trip)	0.6143	0.9909	0.4821	0.6850
Time savings per vehicle	0.3766		0.2029	
Value of savings ($/vehicle-hour) (2)	$ 1.17		$ 1.17	
Annual traffic volume (3)	548		183	
Total value of time savings	$ 242		$ 43	
Trucks, Heavy				
Average speed (miles per hour) (1)	32	19	24	17.5
Distance (miles)	21.5	21.8	13.5	13.7
Time (hours per trip)	0.6719	1.1474	0.5625	0.7829
Time savings per vehicle	0.4755		0.2204	
Value of savings ($/vehicle-hour) (2)	$ 1.47		$ 1.47	
Annual traffic volume (3)	548		183	
Total value of time savings	$ 383		$ 59	
TOTAL ANNUAL TIME ELEMENT SAVINGS	$ 9,472		$ 1,878	

Time Element Savings accrue to traffic as a result of the same factors that result in Mileage Element Savings, i.e. decreased travel distance, rise and fall, and gradient; and improved riding surface and alinement. These factors allow greater speed of travel.

(1) The average speeds used in the above table were based on data published in Oregon Technical Bulletin No. 7, p.320.

(2) The value of savings ($ per vehicle-hour) were based on data published in Oregon Technical Bulletin No. 7, p.322.

(3) Annual traffic volume is taken from column 2 of C. Annual Revenue, p. 6 this report, which in turn is derived by multiplying A.D.T. by 365, the number of days in a year.

F. TRAFFIC BENEFITS

Route F.A.S. 324 and Proposed Extension, Beaverhead County, Montana, November 1946

	Route F.A.S. 324		Proposed Extension	
	Fuel Function	Non-fuel Function	Fuel Function	Non-fuel Function
ileage Element Factors				
istance savings	$ 259	$ 423	$ 70	$ 115
oadway surface savings	5,371	6,836	540	584
ise and fall savings	70	0	65	0
linement savings	-	0	37	0
radient savings	988	987	188	188
otal mileage savings	$6,688	$ 8,246	$900	$ 887
ime Element Factors				
assenger cars		$ 5,511		$1,022
rucks, light		3,336		754
rucks, medium		242		43
rucks, heavy		383		59
otal time Element savings		$ 9,472		$1,878
otal Fuel Function Benefits		$ 6,688		$ 900
otal Non-fuel Function Benefits		$17,718		$2,765

raffic Benefits: The above tabulation allocates Mileage Element Savings (p. 8) and Time Element Savings (p.11) to a Fuel and Non-fuel Function basis in accordance with proportions developed in the Oregon Technical Bulletin No. 7, p. 327 as follows:

ileage Element Factors:	Fuel Function	Non-Fuel Function
istance savings	38%	62%
oadway surface savings		
Earth to oil	44	56
Earth to gravel	48	52
ise and Fall savings	100	0
radient savings	100	0
linement savings	50	50
ime Element Factors:	0%	100%

G. DERIVATION OF QUOTIENTS

F.A.S. 324, Beaverhead Co., Montana, Nov. 1946

Income, Average annual $= I_{ar} = \$\,9{,}946$

Cost, average annual $= C_a = \$24{,}000$

Benefits, non-fuel $= B_n = \$17{,}718$

Benefits, fuel $= B_f = \$\,6{,}688$

$K_1 = 1.00$

$K_1 C_a = \$24{,}000$

Solvency Quotient $= Q_s = I_{ar}/K_1 C_a = 9{,}946/24{,}000 = 0.4144$

Non-fuel Benefit Quotient $= Q_{Bn} = B_n/K_1 C_a = 17{,}718/24{,}000 = 0.7383$

Fuel Benefit Quotient $= Q_{Bf} = B_f/K_1 C_a = 6{,}688/24{,}000 = 0.2787$

Composite Solvency Quotient $= Q_c = 0.707(Q_s + Q_{Bn} + Q_{Bf}) = 0.707\ (1.4314) = 1.012$

Proposed Extension to F.A.S. 324, Beaverhead Co., Montana, Nov. 1946

Income, average annual $= L_{ar} = \$\,2{,}346$

Cost, average annual $= C_a = \$17{,}654$

Benefits, non-fuel $= B_n = \$\,2{,}765$

Benefits, fuel $= Bf = \$\ \ 900$

$K_1 = 11{,}348/17{,}654 = 0.6428$

$K_1 C_a = \$11{,}348$

Solvency Quotient $= Q_s = I_{ar}/K_1 C_a = 2{,}346/11{,}348 = 0.2067$

Non-fuel Benefit Quotient $= Q_{Bn} = B_n/K_1 C_a = 2{,}765/11{,}348 = 0.2437$

Fuel Benefit Quotient $= Q_{Bf} = B_f/K_1 C_a = 900/11{,}348 = 0.0793$

Composite Solvency Quotient $= Q_c = 0.707(Q_s + Q_{Bn} + Q_{Bf}) = 0.707\ (0.5297) = 0.3745$

G. DERIVATION OF QUOTIENTS (cont'd)

F.A.S. 324 combined with Proposed Extension, Beaverhead Co., Montana, Nov. 1946

Income, average annual $= I_{ar} = \$12,292$

Cost, average annual $= C_a = \$41,654$

Benefits, non-fuel $= B_n = \$20,483$

Benefits, fuel $= B_f = \$\ 7,588$

$K_1 = 35,348/41,654 = 0.8486$

$K_1 C_a = \$35,348$

Solvency Quotient $= Q_s = I_{ar}/K_1 C_a = 12,292/35,348 = 0.3477$

Non-fuel Benefit Quotient $= Q_{Bn} = B_n/K_1 C_a = 20,483/35,348 = 0.5795$

Fuel Benefit Quotient $= Q_{Bf} = B_f/K_1 C_a = 7,588/35,348 = 0.2147$

Composite Solvency Quotient $= Q_c = 0.707(Q_s+Q_{Bn}+Q_{Bf}) = 0.707 \quad (1.1419) = 0.8073$

Notes on Constants and Quotients

K_1 = The pro rata of total annual cost which is to be defrayed from road users funds.

Q_s = The Solvency Quotient serves as a measure of the financial soundness or economic expediency of selecting any newroute for addition to an existing highway system.

Q_c = The Composite Solvency quotient expresses numerically the composite desirability or order or preference for any project when road user benefits as well as highway incomes are considered.

SUMMARY TABLE OF SOLVENCY RESULTS

Quotient Descriptions	Route Designation		
	F.A.S. 324	Prop. Extn.	Comb. Total
Q_s : Annual Revenues ÷ Annual Capital Costs	0.414	0.207	0.348
Q_{Bn}: Annual Non-fuel Benefits ÷ Annual Capital Costs	0.738	0.244	0.580
Q_{Bf}: Annual Fuel Benefits ÷ Annual Capital Costs	0.279	0.079	0.215
Q_c : Composite Solvency	1.012	0.375	0.807

V. RECOMMENDATION

The Oregon State Highway Department has attempted to reduce to a dollars and cents valuation, the many various factors that, balanced against each other, make the construction of a road feasible or unfeasible. They have further combined these valuations in such a manner as to arrive at one final figure which serves both as an index for comparison of various routes and also as a criterion of the value of each road to the communities served by it and to the state.

It is impossible for any one man to "carry in his head" a proper consideration of the relative values for all these factors and arrive at precise standards of comparability for thelarge number of roads to be rated. Now would any two men, however reliable their judgement, arrive at identical comparisons for a large number of projects.

Therefore, this reasonable method of applying engineering and economic principles that reduce the wide variations in personal judgement to a more standard practice resulting in a good index for comparison and valuation, serves a useful purpose.

So in accordance withthe Oregon Highway Department's method, we have developed the mathematical relationships between estimated costs and possible future revenues and benefits, with final results as shown in the Summary Table of Solvency Results, above.

By way of interpretation, F.A.S. 324 will return 41.4% of its cost in gasoline tax revenue. When the value to the road users of increased vehicle life and decreased vehicle operating costs and travel time (due to decreased travel distance, riseand fall; better road surface, gradient and alinement, etc.) is added, the percentage of cost that may be repaid is raised to 101.2%. Thus F.A.S. 324 is solvent and will pay for itself.

The combined routing, including the Proposed Extension, gives a percentage of 80.7. It is expected that the Forest Service will improve the first six miles from Bannock Pass north. If, after the State Highway Department has improved F.A.S. 324, the county should gravel surface and otherwise improve their remaining 7.6 miles, it is quite possible that costs would be so reduced and traffic increased that the combined routing's rating would be raised to complete solvency.

As stated previously on page 1, it is expected that the income producing roads should have their profits used for the construction of lesser income producing roads as long as the entire system remains solvent.

Therefore, in conclusion, we state that F.A. Secondary 324 should be constructed from Armstead to Brenner.

It is further recommended that F.A.S. 324 be extended to the Idaho boundary by the addition of 13.7 miles of secondary road consisting of 7.7 miles of county road and six miles of Forest Service road; and that this additional mileage be constructed when funds are available. This preference is supported by a potential traffic flow from the Idaho area. The complete route has inherent possibilities of becoming completely solvent soon after completion of construction.